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Cosmic-Ray-Produced Stable Isotopes in Iron Meteorites

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Abstract. The isotopic composition of vanadium, calcium, and potassium extracted from several iron meteorites was measured. The isotopes V^{50}, Ca^{46}, Ca^{48}, and K^{40} were found to be strongly enriched by cosmic-ray-induced spallation reactions. The concentrations of these isotopes were determined by isotopic dilution techniques. The results are compared with data on cosmogenic Sc^{45} and rare gas isotopes in order to determine the distribution of stable spallation products. The concentration $C(A,Z)$ of a stable spallation product can be given as a function of the total mass loss $\Delta A = 56 - A$ by the equation

$$C(A, Z) = \gamma(A, Z)k_1(\Delta A)^{-k_2}$$

where $\gamma = 1$ for cumulative and $0<\gamma<1$ for noncumulative isotopes. This equation is experimentally verified for a wide range of ΔA. The constants k_1 and k_2 were calculated for each meteorite. Especially from the constants k_2 we obtain information concerning the location of the samples inside of the preatmospheric meteorite bodies. Exposure ages were estimated by comparing the concentrations of K^{40} with those of stable isotopes. Comparison with Cl^{36}-Ar^{36} exposure ages indicates an essentially constant cosmic-ray bombardment during the time of exposure.

INTRODUCTION

The detectability of cosmic-ray-produced stable isotopes in meteorites is limited by the presence of primordial matter. Usually only rare isotopes of rare elements can be detected. Since meteorites lost most of the primordial rare gases early in their history, cosmic-ray-produced rare gas isotopes are easily measurable. *Wänke* [1960] found that most of the isotope Sc^{45} in iron meteorites is of cosmogenic origin. Since scandium has only one stable isotope, some uncertainty remains as to what fraction of the total scandium is of cosmogenic origin.

Recently, *Stauffer and Honda* [1961] reported that vanadium extracted from the iron meteorite Aroos is strongly enriched in V^{50}, produced by cosmic-ray-induced spallation reactions. The amount of cosmic-ray-produced V^{50} was measured by using isotopic dilution techniques. This work has been continued, and the abundances of cosmogenic V^{50} in six additional iron meteorites have been measured. These results are presented in a subsequent section.

Calcium is another element which is especially suitable for such measurements. Its abundance in iron meteorites is very low. *Wänke* [1958] found less than 1 ppm Ca in the Carbo iron meteorite by using neutron activation techniques. Ca^{46} is the isotope with the smallest terrestrial abundance. A large enrichment is also expected to be found for the isotope Ca^{48}, however, because of its much higher cosmogenic production rate.

In our investigation of the isotopic composition of calcium extracted from several iron meteorites the isotopes Ca^{48} and Ca^{46} were found to be enriched appreciably. In some cases a small enrichment of the isotopes Ca^{42} and Ca^{44} was observed. The absolute amounts of cosmic-ray-produced Ca^{48} and Ca^{46} were determined by isotopic dilution techniques.

In addition to the calcium and vanadium measurements, we determined the concentration of the long-lived radioactive isotope K^{40} in the same iron meteorites.

The primordial abundances of most elements with A smaller than 56 are much larger in stone meteorites than in iron meteorites. Spallation-induced enrichments of stable, nonvolatile isotopes are only detectable in the separated metal phase. However, the degrees of enrichment are

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precipitate was removed by centrifuge. Calcium oxalate was recovered by adding ammonium oxalate. The salt was attacked by H_2SO_4, and the excess of acid was expelled at higher temperature.

Throughout the process, plastic and silica wares were used in order to avoid laboratory contamination.

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